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TRAINING-INDUCED CHANGES IN THE TOPOGRAPHY OF MUSCLE TORQUES AND MAXIMAL MUSCLE TORQUES IN BASKETBALL PLAYERS

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ABSTRACT: The aim of the study was to detect changes in the maximal muscle torques in male basketball players during a two-year training cycle. We verified the hypothesis that different workloads applied during the preparation and competition periods would result in changes in the maximal muscle torques of the athletes (increase during the former and decrease or no change during the latter period) accompanied by no alteration of the percent muscle topography of all the muscle groups tested. The examinations were conducted on nine senior male basketball players from the Polish national team. Estimations of the muscle torques in static conditions were performed at the end of the preparation (measurements I and III) and competition (measurements II and IV) periods of a two-year training cycle. Eleven muscle groups were studied including flexors and extensors of the trunk and flexors and extensors of the shoulder, the elbow, the hip, the knee, and the ankle. Muscle torques of the shoulder and the elbow insignificantly decreased except for the muscle torque of the flexors of the shoulder. Muscle torques of the flexors and extensors of the trunk as well as of the flexors and extensors of the hip, the knee, and the ankle increased between measurements I and III and between measurements I and IV with the only exception being the muscle torque of the flexors of the knee (which significantly decreased by 7.4%). In the case of the flexors and extensors of the trunk and the flexors and extensors of the hip, the changes appeared to be significant. The sum of the muscle torques of the upper limbs markedly decreased between the preparation (measurement I) and competition (measurement IV) periods. The sum of the muscle torques of the trunk and the lower limbs and the sum of the muscle torques of the eleven muscle groups significantly increased between measurements I and IV. Percent muscle topography significantly decreased for the flexors and extensors of the shoulder and the elbow. Likewise, the muscle topography for the sum of the upper extremities was significantly reduced. No changes in the "flexors-extensors" indices of the shoulder, the elbow, the hip, and the knee were observed during the two-year training cycle.

KEY WORDS: maximal muscle torque, percentage muscle topography, basketball

INTRODUCTION

In estimations of competitiveness of the motor system of athletes, changes in the maximal muscle torques may reflect the results of the applied training loads. To this end, the most often used parameter is the maximal muscle torque exerted by groups of flexors and extensors of the lower and upper extremities and the trunk in both static and dynamic conditions [4-7,11,14,17,18,22,30,33]. Muscle torques may also be expressed as the contribution of particular muscle groups to their sum [3,5,6,17,30]. Physical effort in basketball consists of various portions of aerobic and anaerobic workloads. Observations of basketball matches indicate that efficiency in this sport depends on the ability of the athletes to make short explosive efforts (starts, stops, jumps). According to Zając and Cholewa [35], aggressive forms of defence and prevalence of the fast attack during a basketball match result in over 60% of the effort of the player being covered by anaerobic metabolism. On the other hand, prevalence of the retreated defence and positional attack are associated with combined metabolism. Arrival at the appropriate level of competitiveness in basketball depends on numerous factors. Hence, control of the training process in this sport should refer not only to the applied training workloads but also to the level of the general and specific fitness of the athletes based on the strength of their muscles.

In the present study we aimed to detect changes in the maximal muscle torques in basketball players during a two-year training cycle. Specifically, we tested the hypothesis that different training workloads applied during separate training periods would result in alteration of the maximal muscle torques (i.e., their increase during the preparation cycle and no change or a decrease during the competition cycle), whereas the topography of individual muscle groups would remain unaltered.

MATERIALS AND METHODS

Nine senior male basketball players from the Polish national team were recruited to participate in the study. In these subjects two measurements (I and III) of body mass were made at the end of the two-year training cycle (March) and two similar measurements (II and IV) were performed at the end of the preparation period (September). Mean values ± SD of the subjects' parameters were as follows: age – 22.3 ± 2.6 years; height – 202.3 ± 5.3 cm; body mass – 92.9 ± 8.9 kg (measurement I), 93.7 ± 9.8 kg (measurement II), 95.4 ± 9.2 kg (measurement III), 94.2 ± 9.8 kg (measurement IV); and training experience – 8.2 ± 2.2 years. When the estimated body masses were compared, significant differences were detected between measurements I and III and between measurements II and III.

Estimations of the static maximal muscle torques for eleven muscle groups including flexors and extensors of the limbs in the elbow, the shoulder, the hip, and the knee, flexors and extensors of the trunk, and plantar flexors of the foot were conducted at a station designed for measurements of maximal muscle torques in static conditions [5,6,8,34].

Muscle torques of the flexors and extensors of the limb in the elbow were measured in a standing position with the trunk leaning against a wall and stabilized, the arm rested on a support, the shoulder joint angled at 90˚ and the forearm bent perpendicularly to the arm.

Muscle torques of the flexors and extensors of the upper limb in the shoulder were also measured in the standing position with the shoulder joint angled at 0˚. The trunk of the athlete was leaning against the station frame and was stabilized by his second arm holding the frame as well as by an assistant pressing the subject's chest against the frame.

Muscle torques of the flexors and extensors of the lower limb in the knee and the flexors and extensors of the trunk were measured in the sitting position with the hip and knee joints angled at 90˚ and the arms resting on the chest. The subject's body was stabilized by belts fastened across the anterior iliac spines and the distal parts of the thighs.

Extensors and flexors of the lower limb in the hip were examined in the supine and prone positions, respectively, with the hip angled at 90˚. The subject stabilized his trunk holding the station's frame and, during examination of the flexors, also by pressing his pelvis against a support.

Plantar flexors of the foot were tested in the sitting position with the examined leg bent at the knee and the hip at 90˚. The athlete was holding on to the seat with his hands. The lower extremity was stabilized with a steel clamping ring enclosing the hip from the top, front and both sides.

The measured values of the maximal muscle torques of the flexors and extensors of the extremities in the elbow, the shoulder, the hip, and the knee and the flexors and extensors of the trunk were used to calculate the "flexors-extensors" index [28,30].

All the assessments were performed in the morning. The subjects were informed about the aim and methodology of the study.

For verification of the obtained results, analysis of variance (ANOVA) with repeated measurements was used. Statistical significance of the differences between means was computed post hoc using the least significant difference (LSD) test. Relationships between the muscle torques and the body mass were assessed by calculating Pearson's linear correlation coefficients. In the conducted statistical analyses, p values less than 0.05 were regarded as significant. All the calculations were performed using the STATISTICA™ 5.5 package (StatSoft, Poland).

TABLE 1. CHANGES IN MEAN VALUES (±SD) OF THE MAXIMAL MUSCLE TORQUES [N·m] OF THE FLEXORS (F) AND EXTENSORS (E) OF THE ELBOW, SHOULDER, HIP, KNEE, AND ANKLE JOINTS, THE FLEXORS AND EXTENSORS OF THE TRUNK, AND THE SUM OF THE MUSCLE TORQUES OF THE UPPER (SUE) AND LOWER (SLE) EXTREMITIES, THE TRUNK (ST), AND ELEVEN MUSCLE GROUPS (SUM) DURING THE TWO-YEAR TRAINING CYCLE

Joint		Measurement I	Measurement II	Measurement III	Measurement IV
Elbow	F	105.2 ± 13.1	110.1 ± 19.3	105.7 ± 12.6	101.9 ± 11.3
	E	69.8 ± 10.3	76.6 ± 11.9	67.6 ± 16.5 ^{b}	64.4 ± 13.7 ^{b}
Shoulder	F	165.0 ± 26.6	159.9 ± 33.0	159.8 ± 22.5	148.1 ± 18.8 ^{a}
	E	128.6 ± 19.3	134.6 ± 32.1	137.7 ± 17.3	121.3 ± 11.6 ^{c}
Hip	F	176.3 ± 35.9	218.6 ± 47.6 ^{a}	237.9 ± 21.0 ^{a}	223.8 ± 27.6 ^{a}
	E	502.4 ± 56.1	587.7 ± 122.0	615.7 ± 112.9 ^{a}	619.6 ± 91.4 ^{a}
Knee	F	203.8 ± 21.9	208.4 ± 32.5	216.6 ± 30.4	191.0 ± 34.9 ^{c}
	E	268.3 ± 29.4	272.3 ± 47.9	284.9 ± 59.8	283.7 ± 62.8
Ankle	F	237.0 ± 51.9	227.9 ± 34.9	246.8 ± 43.3 ^{b}	250.7 ± 41.7 ^{b}
Trunk	F	326.3 ± 60.6	366.7 ± 65.4 ^{a}	352.3 ± 82.4	385.1 ± 91.3 ^{a}
	E	692.9 ± 219.3	719.1 ± 142.4	754.4 ± 136.6	839.0 ± 186.1 ^{ab}
SUE		468.6 ± 59.0	481.1 ± 87.6	470.7 ± 52.0	435.8 ± 29.9 ^{abc}
SLE		1387.9 ± 129.0	1514.9 ± 236.5	1601.8 ± 191.4 ^{a}	1568.7 ± 199.5 ^{a}
ST		1019.2 ± 220.2	1085.8 ± 127.5	1106.8 ± 174.1	1224.1 ± 213.1 ^{abc}
SUM		2875.7 ± 371.1	3081.8 ± 403.7 ^{a}	3179.2 ± 343.0 ^{a}	3228.6 ± 324.6 ^{ab}

Note: ^{a} – indicates statistically significant difference from measurement I, ^{b} – indicates statistically significant difference from measurement II, ^{c} – indicates statistically significant difference from measurement III

RESULTS

Maximal muscle torques (MT) and relative muscle torques estimated in the tested basketball players are shown in Tables 1 and 2, respectively. In the case of MT of the flexors and extensors of the upper limb in the elbow and the shoulder, slight increases in their values were detected between measurements I and II followed by insignificant decreases noted for all the muscles except for the flexors of the shoulder. Maximal muscle torques of the flexors and extensors of the lower extremity in the hip and the knee, the plantar flexors of the foot, and the flexors and extensors of the trunk increased between measurements I and III as well as between measurements I and IV (in the case of the flexors and extensors of the hip and the trunk the increases were significant); the only exception was the flexors of the knee, whose MT significantly decreased by 7.4%. The sum of the maximal muscle torques of the upper limb insignificantly increased between measurements I and II and then decreased (a significant reduction was observed between measurements I and IV). The sums of the maximal muscle torques for the lower limb, the trunk, and the eleven muscle groups tested significantly increased between measurements I and IV.

When the maximal muscle torques estimated at the end of the competition cycle (measurements I and III) were compared, significant changes were recorded for the extensors of the elbow (decrease by 4.4%), the extensors and flexors of the hip (increase by 21.2 and 35.8%, respectively), the sum of the maximal muscle torques of the lower extremity (increase by 12.6%), and the sum of the maximal muscle torques of the eleven muscle groups (increase by 8.3%). In the case of the maximal muscle torques estimated at the end of the preparation cycle (measurements II and IV), significant changes were detected for the extensors of the elbow (decrease by 15.0%), the plantar flexors of the foot in the ankle (increase by 9.4%), and the flexors of the trunk (increase by 17.4%). The sum of the muscle torques of the upper extremity was significantly reduced by 8.1% and the sum of the maximal muscle torques of the muscles of the trunk was significantly elevated by 12.2%.

Mean values of the contribution of individual muscle groups to their sum are presented in Table 3. A significant alteration in the topography of the muscle torques was detected for extensors of the elbow as well as for the flexors and extensors of the shoulder. Also, the contribution of the sum of the maximal muscle torques of the upper limb to the total sum of the maximal muscle torques of the eleven muscle groups examined was markedly reduced.

In the two-year training cycle, a significant correlation between the body mass and the maximal muscle torques of the plantar flexors of the foot and the sum of the muscle torques of the eleven muscle groups was demonstrated. In the case of the maximal muscle torques of the flexors of the elbow, extensors of the knee, and flexors of the trunk, no significant correlation was found. In the remaining cases, a significant relationship between the body mass and the maximal muscle torque was occasionally detected (Table 3).

The calculated values of the "flexors-extensors" indices for the elbow, the shoulder, the hip, the knee, and the trunk remained unchanged during the two-year training cycle (Table 4).

DISCUSSION

Assessment of physical characteristics of an athlete is one of the important features of the training process. Numerous reports have been published on exercise physiology in basketball players [2,9,20,26], but biomechanical investigations in these athletes (involving changes in the physical characteristics) [1,16,24] have been less frequent.

TABLE 2. CHANGES IN MEAN VALUES (±SD) OF THE RELATIVE MAXIMAL MUSCLE TORQUES [$N \cdot m \cdot kg^{-1}$] OF THE FLEXORS (F) AND EXTENSORS (E) OF THE ELBOW, SHOULDER, HIP, KNEE, AND ANKLE JOINTS, THE FLEXORS AND EXTENSORS OF THE TRUNK, AND THE SUM OF THE MUSCLE TORQUES OF THE UPPER (SUE) AND LOWER (SLE) EXTREMITIES, THE TRUNK (ST), AND ELEVEN MUSCLE GROUPS (SUM) DURING THE TWO-YEAR TRAINING CYCLE

Joint		Measurement I	Measurement II	Measurement III	Measurement IV
Elbow	F	1.13 ± 0.11	1.17 ± 0.17	1.11 ± 0.12	1.09 ± 0.15
	E	0.75 ± 0.11	0.81 ± 0.13	0.71 ± 0.08 [b]	0.69 ± 0.12 [b]
Shoulder	F	1.78 ± 0.22	1.69 ± 0.22	1.68 ± 0.20	1.58 ± 0.18 [a]
	E	1.38 ± 0.14	1.43 ± 0.27	1.44 ± 0.13	1.30 ± 0.15
Hip	F	1.89 ± 0.29	2.34 ± 0.46 [a]	2.51 ± 0.27 [a]	2.39 ± 0.37 [a]
	E	5.45 ± 0.79	6.25 ± 0.94	6.44 ± 0.94 [a]	6.67 ± 1.42 [a]
Knee	F	2.19 ± 0.14	2.23 ± 0.34	2.27 ± 0.24	2.03 ± 0.35 [c]
	E	2.91 ± 0.39	2.91 ± 0.60	3.00 ± 0.49	3.04 ± 0.73
Ankle	F	2.54 ± 0.42	2.43 ± 0.27	2.58 ± 0.32	2.66 ± 0.29 [b]
Trunk	F	3.51 ± 0.48	3.92 ± 0.56 [a]	3.69 ± 0.71	4.09 ± 0.85 [ac]
	E	7.40 ± 1.87	7.72 ± 1.45	7.95 ± 1.47	8.84 ± 1.14 [ab]
SUE		5.04 ± 0.38	5.11 ± 0.59	4.94 ± 0.36	4.65 ± 0.38 [ab]
SLE		14.98 ± 1.19	16.16 ± 1.85	16.80 ± 1.33 [a]	16.80 ± 2.66 [a]
ST		10.90 ± 1.61	11.63 ± 1.27	11.64 ± 1.72	12.94 ± 1.10 [abc]
SUM		30.92 ± 2.29	32.91 ± 3.01 [a]	33.38 ± 2.47 [a]	34.39 ± 2.67 [a]

Note: [a] – indicates statistically significant difference from measurement I, [b] – indicates statistically significant difference from measurement II, [c] – indicates statistically significant difference from measurement III

TABLE 3. CHANGES IN MEAN VALUES (±SD) OF THE TOPOGRAPHY OF THE MUSCLE TORQUES [%] AND LINEAR CORRELATION COEFFICIENTS BETWEEN BODY MASS AND MAXIMAL MUSCLE TORQUES OF THE FLEXORS (F) AND EXTENSORS (E) OF THE ELBOW, SHOULDER, HIP, KNEE, AND ANKLE JOINTS, THE FLEXORS AND EXTENSORS OF THE TRUNK, AND THE SUM OF THE MUSCLE TORQUES OF THE UPPER (SUE) AND LOWER (SLE) EXTREMITIES, THE TRUNK (ST), AND ELEVEN MUSCLE GROUPS (SUM) DURING THE TWO-YEAR TRAINING CYCLE

Joint		Measurement				Measurement			
		I	II	III	IV	I	II	III	IV
Elbow	F	3.7 ± 0.3	3.6 ± 0.6	3.3 ± 0.4	3.2 ± 0.3	0.63	0.59	0.52	0.24
	E	2.4 ± 0.3	2.5 ± 0.4	2.1 ± 0.2 [ab]	2.0 ± 0.3 [ab]	0.62	0.69 *	0.83 *	0.16
Shoulder	F	5.7 ± 0.4	5.2 ± 0.6 [a]	5.0 ± 0.5 [a]	4.6 ± 0.6 [ab]	0.54	0.87 *	0.55	0.48
	E	4.5 ± 0.6	4.3 ± 0.6	4.4 ± 0.6	3.8 ± 0.4 [abc]	0.77 *	0.65	0.64	0.34
Hip	F	6.1 ± 1.0	7.1 ± 1.2 [a]	7.5 ± 0.8 [a]	6.9 ± 0.7	0.70 *	0.36	0.28	0.18
	E	17.7 ± 2.5	18.9 ± 2.1	19.4 ± 2.9	19.2 ± 2.6	0.06	0.74 *	0.66	0.29
Knee	F	7.1 ± 0.6	6.8 ± 0.9	6.8 ± 0.7	5.9 ± 1.0 [abc]	0.84 *	0.39	0.62	0.40
	E	9.4 ± 1.2	8.8 ± 1.2	9.0 ± 1.1	8.8 ± 1.5	0.07	0.35	0.36	0.04
Ankle	F	8.2 ± 1.0	7.4 ± 0.9	7.7 ± 0.7	7.7 ± 0.8	0.70 *	0.67 *	0.70 *	0.74 *
Trunk	F	11.4 ± 2.0	12.0 ± 2.0	11.1 ± 2.0	12.0 ± 2.7	0.61	0.50	0.48	0.35
	E	23.7 ± 4.5	23.4 ± 3.6	23.7 ± 3.3	25.8 ± 3.7	0.60	0.21	0.27	0.88 *
SUE		16.3 ± 0.7	15.6 ± 1.3	14.8 ± 1.2 [a]	13.6 ± 0.9 [ab]	0.78 *	0.82 *	0.77 *	0.59
SLE		48.5 ± 3.3	49.1 ± 2.3	50.4 ± 2.8	48.6 ± 4.2	0.66	0.69 *	0.77 *	0.13
ST		35.2 ± 3.3	35.4 ± 2.7	34.8 ± 3.6	37.8 ± 4.4	0.77 *	0.49	0.44	0.92 *
SUM						0.81 *	0.74 *	0.77 *	0.74 *

Note: [a] – indicates statistically significant difference from measurement I, [b] – indicates statistically significant difference from measurement II, [c] – indicates statistically significant difference from measurement III; * – indicates a statistically significant ($p<0.05$) difference

TABLE 4. CHANGES IN MEAN VALUES (±SD) OF THE "FLEXORS-EXTENSORS" INDICES [-] (FEI) DURING THE TWO-YEAR TRAINING CYCLE.

Index	measurement I	measurement II	measurement III	measurement IV
FEI_E	1.55 ± 0.37	1.46 ± 0.24	1.59 ± 0.25	1.61 ± 0.29
FEI_S	1.30 ± 0.19	1.21 ± 0.18	1.16 ± 0.12	1.23 ± 0.22
FEI_H	0.35 ± 0.06	0.38 ± 0.08	0.40 ± 0.11	0.36 ± 0.04
FEI_K	0.77 ± 0.10	0.78 ± 0.13	0.77 ± 0.12	0.69 ± 0.15
FEI_T	0.50 ± 0.15	0.53 ± 0.15	0.48 ± 0.12	0.47 ± 0.12

Note: E – elbow, S – shoulder, H – hip, K – knee, T – trunk

The aim of a preparation period is to raise physical fitness of an athlete to the highest possible level, whereas during a competition period the attained fitness should remain unchanged as long as possible [32]. Hence, at different training stages alterations in the physical features should be detected. In the present study, increases in the maximal muscle torques of all the tested muscle groups and their sums were demonstrated between examinations performed at the end of the competition (measurement I) and preparation (measurement II) periods in the first year of the training cycle with the only exception for the relative maximal muscle torques of the flexors of the shoulder, which were insignificantly reduced. The increase was significant in the case of the maximal muscle torques of the flexors of the trunk and the hip as well as in the case of the sum of the torques of the eleven muscle groups tested. In the second year of the examination, reduced values of the muscle torques were detected in the respective phases of the training cycle with the exceptions of the maximal muscle torques of the extensors of the hip and the knee, the plantar flexors of the foot, the flexors and extensors of the trunk, and the sum of the maximal muscle torques for the trunk and the eleven muscle groups. The obtained results did not fully support the hypothesis that the two-year training cycle of basketball players would increase the maximal muscle torques of the tested muscle groups without changing the topography of the torques. During the analysed training period reduced values of the maximal muscle torques were detected for the flexors and extensors of the elbow and the shoulder as well as for the sum of the maximal muscle torques of the upper extremity. Also, decreased values were recorded for the maximal muscle torques of the flexors of the knee. In the remaining cases maximal muscle torques were significantly elevated. The observed changes expressed as percent of the result of the first measurement were higher than those reported by Häkkinen et al. [15] for the strength of the muscles of the lower limbs (3.5%) after one year of the strength training of weightlifters. They were also higher than those reported by Trzaskoma [30] (3.5%) for male and female record-seeking athletes after two years of training. In the latter study, in judokas trained for three years the contribution of the maximal muscle torques of the upper limbs to the sum of the torques of the tested muscles increased by 1.7%, whereas the relative values of the sum of the maximal muscle torques of the upper limb, the trunk, and the sum of the maximal muscle torques of ten tested muscle groups significantly declined by 5.9%, 7.5%, and 4.6%, respectively. During a two-year training cycle the muscle torques increased by 3%. Other authors reported that the sum of the maximal muscle torques estimated in top class wrestlers was markedly (by 4.8%) elevated during the preparation period, although after completion of the competition period it declined to the initial level [19]. In volleyball players, a six-month training period led to significant elevations in the sum of the torques of the main muscle groups and of the upper extremities (by 4.8% and by 13.9%, respectively), but increases in the sum of the muscle torques of the lower extremities (by 3.4%) and the trunk (by 1.3%) were not significant [31].

Numerous studies have been devoted to measurements of the muscle strength or muscle torques [3,4,14,17,22], which have been frequently presented as a contribution of individual muscle groups to their sum [3,5,6,13,17,30]. Fidelus and Skorupski [13] suggested that in senior athletes there are specific sport-related topographies of muscle torques. In the present investigation, topography of the maximal muscle torques was not significantly altered except for the contribution of the flexors and extensors of the elbow and the shoulder as well as for the sum of the torques of the upper limb, which systematically decreased. The demonstrated changes in the muscle torques and topography of the torques of the upper extremity may suggest that the applied training loads were inadequate and that too little emphasis was placed on the development of these muscle groups. A similar tendency can also be identified in other sports, such as volleyball.

Based on the results of measurements of the maximal muscle torques in static conditions, the authors of some reports calculated a strength index defined as the ratio of the maximal torques of flexors to the maximal torques of extensors (a “flexors-extensors” index) [3,10,12,21,28,30]. Thus, Trzaskoma [28] showed that in junior tennis players strength indices for the knee and the hip equalled 0.48 and 0.15, respectively. In turn, Bober and Hay reported that in subjects practising no sport [3] the respective “flexors-extensors” indices for the knee and the hip equalled 0.46 and 0.47, respectively. Based on the data collected by Jaszczuk et al. [21] in his study of representatives of nine different sports, the “flexors-extensors” indices for the knee and the hip ranged from 0.39 to 0.57 and from 0.18 to 0.25, respectively, but for the knees of representatives of six sports these indices fluctuated within a narrower range of 0.49-0.54. Buśko [5] demonstrated that in cadet and junior basketball players up to 19 years of age the “flexors-extensors” ratio for the knee equalled 0.62, as opposed to 0.68 calculated in the senior players; for the hip, the respective indices equalled 0.41, 0.37, and 0.36. In yet another study, Buśko et al. [10] showed that in strength triathlon athletes the “flexors-extensors” index for the knee equalled 0.47 and was lower than in non training subjects (0.63). In turn, Trzaskoma and Trzaskoma [29] reported that in 70 athletes from various sports the “flexors-extensors” ratios for the hip and the knee equalled 0.20 and 0.43, respectively. The values of this index obtained in the present study for the knee and the hip of the basketball players are compatible with the results of Buśko [6] and Buśko et al. [10], who investigated subjects not engaged in any sport and basketball players and demonstrated that for all the analysed joints the ratios were higher than those reported by Trzaskoma [30] for the group of elite athletes. Moreover, in contrast to the results of Shealy et al. [27], who demonstrated alterations in the “flexors-extensors” ratio after eight weeks of sprint training, no significant changes in this index were recorded in the present investigation for all the analysed joints.

In a few reports [12,23] a relationship between muscle strength and body mass has been described. Le Chevalier et al. [20] showed that the mass of the quadriceps of the thigh significantly correlated with the isokinetic moment of the knee (r=0.78), whereas no significant correlation (r=0.33) was found between the muscle mass and the isometric moment of the knee. In turn, Dworak et al. [12] demonstrated a significant correlation between body mass and muscle torques of the flexors and extensors of the hip and the knee, and of the plantar flexors of the foot. In contrast, Pietraszewski et al. [25] could not find any significant correlation between the lean body mass (LBM) and the sum of the muscle torques of the flexors of the right and left knees as well as the sum of the muscle torques of the extensors of the right and left knees. In cadet, junior, and senior basketball players [5], significant correlations were observed between body mass and muscle torques of the extensors of the hip and the sum of the torques of eleven muscle groups. Significant correlations were detected only in the cadet and junior athletes for the flexors and extensors of the hip, the flexors of the knee, and the extensors of the trunk as well as in the junior and senior athletes for the plantar flexors of the foot. In the report of Buśko and Kłossowski [7] no correlation between body mass and muscle torques of eleven muscle groups was detected in the playmaker, wing, and centre basketball players. In the present study, a correlation between body mass and muscle torques of the individual muscle groups was occasionally demonstrated during the two-year training cycle except for the muscle torques of the plantar flexors of the foot and the sum of the muscle torques of the eleven muscle groups tested. These results corroborate the earlier findings of Buśko [5], Buśko and Kłossowski [7], and Pietraszewski et al. [25].

CONCLUSIONS

The obtained results are not fully consistent with the initial hypothesis:

1. During the two-year study, maximal muscle torques of the particular muscle groups of the lower limb and the trunk increased, whereas the torques estimated for the upper limb decreased.
2. After two years of training, the sum of the maximal muscle torques of the lower limb and the trunk and the sum of the eleven muscle groups were significantly elevated, while the sum of the maximal muscle torques for the upper limb decreased.

3. Topography of the muscle torques was not significantly altered except for the percent contributions of the maximal muscle torques estimated for the upper limb.
4. The "flexors-extensors" index did not change significantly during the two-year training cycle.
5. The obtained results may suggest that selection of the training loads was inadequate and that too little emphasis was placed on the development of strength in the muscles of the upper limbs.
6. During the two-year training period the body mass markedly correlated with the maximal muscle torque of the plantar flexors of the foot and the sum of the maximal muscle torques estimated for the eleven muscle groups tested. In the case of the remaining muscles, the values of the maximal muscle torques occasionally significantly correlated with the body mass.

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